<u>5.16.51 FIELD DENSITY AND MOISTURE TESTS OF SOILS BY NUCLEAR GAUGE (Kansas Test Method KT-51)</u>

a. SCOPE

This method of test covers the procedure for measuring the "in-place" density and moisture of soils by the attenuation of gamma and neutron radiation. The intensity of the radiation detected is dependent in part on the density of the material being tested. It should be recognized that the density and moisture determined by this method is not necessarily the average value within the measured volume at any one location. KT-51 reflects testing procedures found in AASHTO T-238 and T-239.

The equipment utilizes radioactive materials which may be hazardous to the health of users unless proper precautions are taken (For KDOT field personnel only: Refer to Standard Operating Manual No. 1.13.2).

b. APPARATUS

b.1. General.

b.1.a. *Probe*. Either the gamma source or the gamma detector shall be housed in a probe for insertion into a preformed hole of the material to be tested. The probe shall be marked in increments of 50 mm (2 in) for tests with probe depths from 50 mm (2 in) to a maximum of 300 mm (12 in). The probe shall be mechanically held in place when it is manually moved to the desired depth.

b.1.b. *Housing*. The source, detector, readout device, probe, and power supply shall be in housings of rugged construction that are moisture and dust proof.

b.1.c. *Guide*. A guide used for the hole forming device to make a hole normal to the prepared surface.

b.1.d. *Hole-forming Device*. An auger, pin, or similar device for forming a hole in the soil to accommodate the probe. The hole-forming device shall have a nominal diameter equal to or up to 3 mm (1/8 in) greater than the probe diameter.

b.2. Standardization.

b.2.a. Standardization of the nuclear gauge on a reference standard block is required at the start of each day's use and when test measurements are suspect.
b.2.b. Warm up the nuclear gauge in accordance with the manufacturer's recommendations.

c. GAUGE PREPARATIONS

c.1. Taking Reference Standard Count.

Put the time switch in the SLOW (4 minute) position and take a reading on the reference standard block. This reading should be within one percent of the previous days reading. If not, repeat the standard count. The two numbers should be within one percent of each other and within two percent of the previous days reading. If not, check the machine for malfunction.

c.2. Checking Density Calibration Curves.

The calibration curves for newly acquired gauges should be checked. **Gauge calibration shall follow 5.21.02 INDEPENDENT ASSURANCE REPLICATE (ASR) CHECK FOR NUCLEAR DENSITY GAUGES.** KDOT gauges shall be calibrated at the Materials and Research Center.

NOTE a: If KT-11 is used for moisture determination instead of the nuclear gauge, then skip **c.3.** Determining Moisture Correction Factor Using the Nuclear Gauge.

c.3. Determining Moisture Correction Factor Using the Nuclear Gauge.

c.3.a. A Determination* by the nuclear method is to be compared with moisture quantities described under KT-11 **b. CONSTANT WEIGHT METHOD**. Moisture samples shall be extracted from the same location the nuclear gauge readings are taken. At least 6 separate locations are required. Discard the location(s) with the greatest deviation to leave 5 pair of samples for analysis. Prepare the test site and proceed as stated in **d. TEST PROCEDURE** of this test method.

* A determination represents 3 one-minute wet density (WD) count readings from the gauge at one location.

c.3.b. Compare the six or more sample pairs of oven dry and nuclear gauge results from the locations listed above in **c.3.a.** Discard the sample pair(s) that deviates the greatest from the remaining five. Oven dry samples are to be at least 1,000 g and are to be taken under the center of the gauge to a depth of 150 to 200 mm (6 to 8 in). Nuclear tests are to be taken without any type of internally applied corrections.

c.3.c. Prepare a chart of sample pairs as shown below:

Sample No.	%M Oven Dry (%M OD)	(% G)	%M Gauge Moisture Diff. (%M OD - %M G)
1	4.5	8.6	-4.1
2	4.0	5.9	-1.9
3	7.2	9.7	-2.5
4	6.7	8.6	-1.9
5 *	3.9 *	9.5 *	-5.6 *
6	4.7	8.6	-3.9
Average	5.4	8.3	-2.9 @

NOTE: "*" represents the discarded sample pair.

@ **NOTE: If the Average Moisture Diff. exceeds +/- one percent, a Moisture Correction Factor will be required for that soil type.**

c.3.d. The difference between the expected to vary from sample to sample due to normal variation. To determine the correction factor, calculate the average difference value and proceed as follows:

Calculate the Moisture Correction Factor using the average difference values, as follows:

$$\text{Moisture Corr. Factor} = \frac{100\,(\text{Avg. \%M Oven dry} - \text{Avg. \%M Gauge})}{100 + \text{Avg. \%M Gauge}}$$

In the example above, the moisture correction would be as follows:

$$\text{Moisture Corr. Factor} = \frac{100\,(5.4 - 8.3)}{100 + 8.3} = -2.7$$

The correction is independent of dry density and adjusts the apparent moisture to true moisture regardless of dry density. This value can be used for all future tests on the same soil type.

NOTE b: Each soil type will have a moisture correction factor.

d. TEST PROCEDURE

d.1. Determine the number of soil types to be encountered on the project. If the number is substantial, then use KT-11 MOISTURE TESTS to determine the correct moisture content of the soil instead of calibrating the nuclear density gauge to moisture. **KT-11 c. GAS PRESSURE "SPEEDY" METHOD** can be used if the Speedy was calibrated within the last year.

d.2. Randomly select a test site where the gauge will be at least 300 mm (12 in) away from any slight vertical projection. If the vertical projection is significant, then maintain a distance of 3 m (10 ft) including all stationary vehicles and construction equipment. Vehicles and construction equipment in motion should maintain a **minimum** distance of 1 to 1.5 m (3 to 4 ft) from the gauge.

d.3. Prepare the test site in the following manner:

d.3.a. Remove all loose and disturbed material, and remove additional material as necessary to expose the top of the material to be tested.

d.3.b. Prepare a horizontal area, sufficient in size to accommodate the gauge by planing a level area to a smooth condition. This will create a maximum contact surface between the nuclear gauge and material being tested.

d.3.c. The maximum void beneath the gauge shall not exceed approximately 3 mm (1/8 in). Use native soil or fine sand to fill the voids and smooth the surface with a rigid plate or other suitable tool. The depth of the filler should not exceed approximately 3 mm (1/8 in).

d.3.d. Place the nuclear gauge on the test site and trace the outline of the gauge onto the test surface. After the site selection has been made, a vertical hole is made 50 mm (2 in) deeper than the thickness of the material, with the rod and plate provided with the gauge. If the thickness of the material exceeds the depth capability of the gauge, then a hole is made 50 mm (2 in) deeper than the gauge's maximum depth. Set the probe to maximum depth or at a depth equal to the project specification thickness, whichever is less. Maintain alignment so the insertion of the probe will not cause the gauge to tilt from the plane of the prepared area.

d.4. Proceed with testing in the following manner:

d.4.a. Tilt the gauge and extend the probe to the position required for the desired depth of test.

d.4.b. Insert the probe in the hole.

d.4.c. Seat the gauge firmly by moving it about the probe with a back and forth motion.

d.4.d. Pull gently on the gauge in the direction that will bring the side of the probe which faces the center of the gauge into intimate contact with the side of the hole.

d.4.e. Set the time for a one-minute reading interval. Initiate the gauge to take the readings.

d.5. Take Gauge Reading

Take and record 3 one-minute readings: Record the kg/m^3 (PCF) on Wet density (WD) and Moisture (M) for each reading. If any individual WD is not within $\pm$ 16 kg/m^3 ($\pm$ 1.0 PCF) of the average, eliminate it along with its M reading from the average. Take another one-minute reading (to replace the values eliminated) and average these values with the non-deviant values. Test this new set of values by the above criteria. If two wet densities are not within $\pm$ 16 kg/m^3 ($\pm$ 1.0 PCF) of the average, discard all three readings and start over again. When three readings meet the above criteria, record the average WD and the average M of the soil.

d.6. Determining Moisture Readings Using KT-11

Determine the moisture content of soil directly under the gauge according to KT-11.

d.7. If the soil fails to meet the designated compaction at a single location, rotate the gauge 180 degrees and take new readings. If the soil compaction still fails, then the compaction is inadequate.

e. CALCULATIONS WHEN USING KT-11

Calculate the Moisture in kg/m^3 (PCF) and subtract that quantity from the Wet Density (WD) determined by the gauge. This will yield the Dry Density (DD):

$$M = \frac{WD\ (\%M)}{(100 + \%M)}$$

$$DD = WD - M$$

$$\%PR = \frac{100\ (DD)}{SD}$$

where: M = Moisture content in kg/m^3 (PCF)
DD = Dry Density in kg/m^3 (PCF)
WD = Wet Density in kg/m^3 (PCF)
%PR = Percent of Proctor Density (also referred to as the Percent of Standard Density)
SD = Standard Density kg/m^3 (PCF)

f. SOIL IDENTIFICATION

f.1. Identification of the soil is required for several reasons. These include the comparison to the standards for optimum moisture content and target density which are required in order to determine compliance with the specifications; determining the proper moisture correction factors to be applied for the soil under test; and the reporting of the moisture and density tests results.

f.2. A selection of soil type is necessary in order to set the moisture correction factor for the gauge.

f.3. Nonhomogeneous soils may be encountered in which differences between gauges and oven are not consistent between samples. In this case, the use of KT-11 MOISTURE TESTS is the proper method for analyzing the moisture content of the soil.

TESTING:

Wet density and moisture are the only items the density gauge is capable of reading. All other values are calculated from wet density, moisture, and initialized information in the gauge.